Circulatory Reactions to Exercise During Convalescence from Infectious Disease

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CIRCULATORY REACTIONS TO EXERCISE DURING CONVALESCENCE FROM INFECTIOUS DISEASE *

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The return of patients to normal after pneumonia, typhoid and typhus fevers and the other infectious diseases is a phenomenon with which we all are familiar clinically, yet convalescence up to the present has not been investigated in any exact or quantitative way. The length of time during which convalescent patients are confined to bed and the resumption of normal life are graduated very differently by different practitioners. In view of this great variation in procedure any accurate or quantitative method by which we could observe the stage of a patient's convalescence would be very desirable.

At present the need for such an accurate method of following a patient's convalescence is rendered acute by the military situation. We have in training a great number of young men, many of whom are being attacked by infectious diseases. In the treatment of these patients efficiency demands that their absence from military duties shall be sufficient for complete convalescence but shall not be prolonged unduly beyond the proper time. If the proper time for convalescence is to be determined, as it is at present, solely by the opinion of the attending physician, it is highly probable that some soldiers will be returned to active service too soon and some too late. In the former case we may do the patient serious injury; in the latter case we shall have wasted time, attention and hospital accommodation at a time when all of these are in great demand. With these considerations in mind we have conducted a series of experiments on patients recovering from acute infections.

We have confined our attention to the circulatory system because of the following considerations: Once the original infection has been overcome, the recovery of the patient means really the recovery of the patient's ability to do muscular work, and the recovery of the patient's ability to do muscular work is essentially a circulatory rather than a muscular phenomenon. The ordinary person in health overtaxes his circulation long before he exhausts his skeletal musculature. The convalescent from infectious disease is limited in his exercise not by what his muscles can do but what his heart can do. This is obvious when we consider that the serious pathologic effects of overexertion, both in health and in disease, are not muscular but circulatory. We cannot

* From the cardiographic laboratory of the Mount Sinai Hospital.

easily overwork a skeletal muscle, because it has a very efficient safety device—refusal to respond. We can overwork the circulatory system, because refusal to respond adequately on its part does not result in immediate cessation of work. Therefore, it seemed logical to determine the circulatory reactions following muscular work at different periods during convalescence to see if we could discover any change in these reactions which might afford a criterion of the return to normal of the circulation.

The patients whose recovery we have followed have all been men between the ages of 21 and 45 years. There are ten cases in our series: seven pneumonias; one pleurisy; one typhoid fever; one typhus fever.

Our procedure has been as follows: The pulse rate was taken several times until it reached a constant figure. The systolic blood pressure was read by auscultation (using a mercury sphygmomanometer) until it reached its normal level. Then the patient performed a definite amount of work. The pulse rate was counted for 15 seconds immediately after the work and, at the end of 110 seconds, it was counted again for 20 seconds. From these two figures the rates immediately after exercise and at the end of 120 seconds were calculated. The systolic blood pressure was taken by the method described by Barringer[1] and also, in some cases, by the method of Cotton, Rapport and Lewis.[2] Our exercises have consisted in sitting up in bed and in flexing and swinging dumb-bells of various weights. We have calculated the work done in foot-pounds. The calculation of work done is fairly accurate and the error is constant for the same patient, so that slight inaccuracies will not vitiate our conclusions.

The method of Barringer[1] consists in taking the systolic pressure before exercise and then taking three readings after exercise—the first between 25 and 30 seconds; the second between 55 and 60 seconds; the third between 85 and 90 seconds—the endeavor being to make the readings as close to 30, 60 and 90 seconds as possible. The method described by Cotton, Rapport and Lewis[2] consists in taking the first reading as soon after exercise as possible and in taking numerous readings thereafter at very short intervals. These readings, when plotted, give us a curve which shows the variations in the systolic pressure after exercise. For reasons which we give later we have used Barringer's method in the majority of our experiments. Our technic has been standardized during the past four months by testing the circulatory reactions of a number of normal persons and of many patients suffering from cardiac insufficiency.

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1. Barringer, T. B., Jr.: Studies of the Heart's Functional Capacity, The Archives Int. Med., 1917, **20,** 829.

2. Cotton, T. F.; Rapport, D. L., and Lewis, T.: After Effects of Exercise on Pulse Rate and Systolic Blood Pressure in Cases of "Irritable Heart," Heart, 1917, **6,** 269.

Barringer believes that a "delayed rise" ("delayed summit," Cotton, Rapport and Lewis) indicates the overtaxing of the cardiac reserve power. A reading at sixty seconds after exercise which is 4 mm. or more higher than the reading at thirty seconds has been taken as indicative of a delayed summit. We have generally been able to produce a delayed summit much more pronounced than this minimum.

The following typical normal series of tests will illustrate the method of testing and recording. The subject was a normal man, 26 years old, weighing 160 pounds.

His systolic blood pressure at rest was................	130
He swung two 10-pound dumb-bells 10 times	
(Calculated work = 2,400 foot-pounds)	
His systolic pressure after work was—at 30 seconds....	150
at 60 seconds....	140
at 90 seconds....	130
In 5 minutes his systolic pressure at rest was constant at	120
He swung two 10-pound dumb-bells 25 times	
(Calculated work = 6,000 foot-pounds)	
His systolic pressure after work was—at 30 seconds....	152
at 60 seconds....	152
at 90 seconds....	144
In 5 minutes his systolic pressure at rest was constant at	125
He swung two 10-pound dumb-bells 30 times	
(Calculated work = 7,200 foot-pounds)	
His systolic pressure after work was—at 30 seconds....	150
at 60 seconds....	164 (delayed summit)
at 90 seconds....	156

In tabulated form the record reads as follows:

130		120		125	
2 × 10 S. 10 (2,400)		2 × 10 S. 25 (6,000)		2 × 10 S. 30 (7,200)	
30.........	150	30.........	152	30.........	150 (delayed summit)
60.........	140	60.........	152	60.........	164
90.........	130	90.........	144	90.........	156

Graphically the record would appear in Chart 1.

We can express the fact that the subject showed a delayed summit after doing 7,200 foot-pounds of work and did not show a delayed summit after 6,000 foot-pounds of work as in Chart 2.

We have omitted any mention of the time in which the work is done. Patients soon acquire a regular rhythm in working, the time of each swing being the same (2 to 3 seconds). Thus, the time factor becomes a constant and can be left out of consideration.

The accompanying series of charts (Charts 3, 4, 5 and 6) shows the change in reactions of the blood pressure to muscular work during convalescence.

It will be observed that all the convalescent patients show the same phenomenon—a progressive increase in the amount of work that can be done without causing a delayed summit of blood pressure. This increase in all cases was synchronous with subjective symptoms of

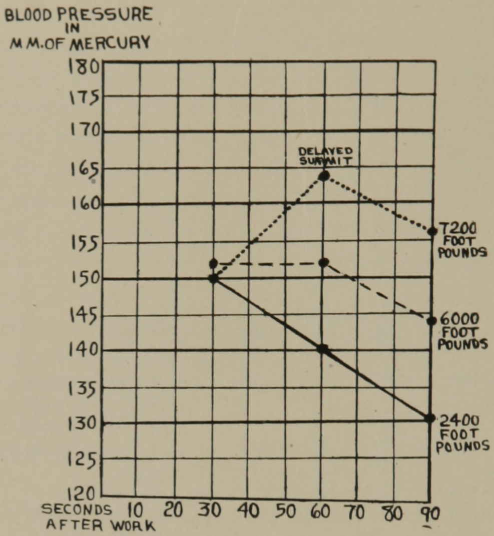

Chart 1.—This chart shows a typical series of blood pressure readings after increasing amounts of work. The subject was a normal man 26 years old. Note that after a small amount of work the pressure falls rapidly; after a greater amount of work the return to normal is not so rapid; after a still greater amount of work the blood pressure continues to increase for some time—"delayed summit." The blood pressure before exercise was about 125.

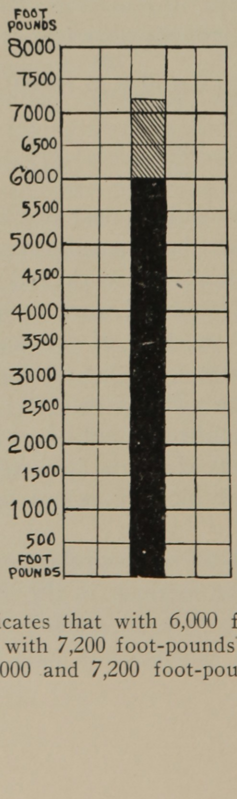

Chart 2.—This chart indicates that with 6,000 foot-pounds of work or less there is no delayed summit; with 7,200 foot-pounds of work or more there is a delayed summit; between 6,000 and 7,200 foot-pounds the circulatory reaction to work changes.

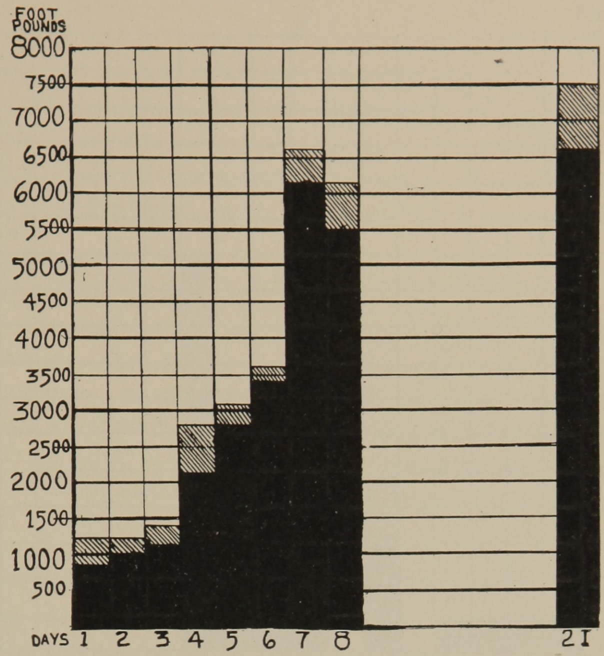

Chart 3

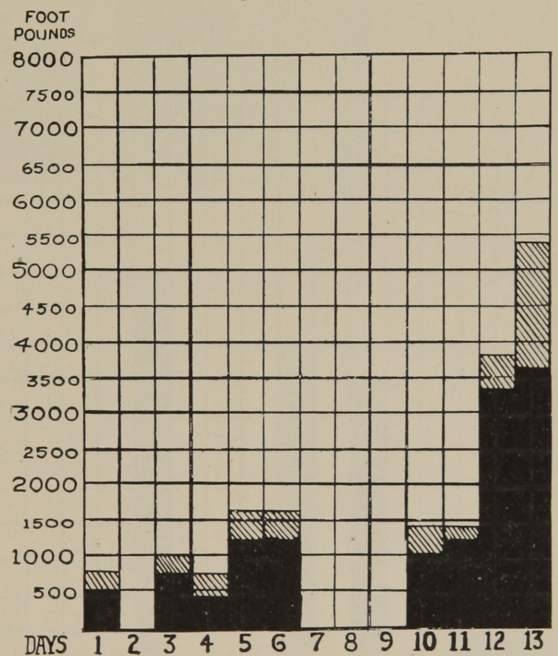

Chart 4

Charts 3 and 4.—These charts show the change in the circulatory reaction to exercise which takes place during convalescence. Chart 3 is from the patient I. M. in Table 1; Chart 4 is from the patient C. B. in Table 1.

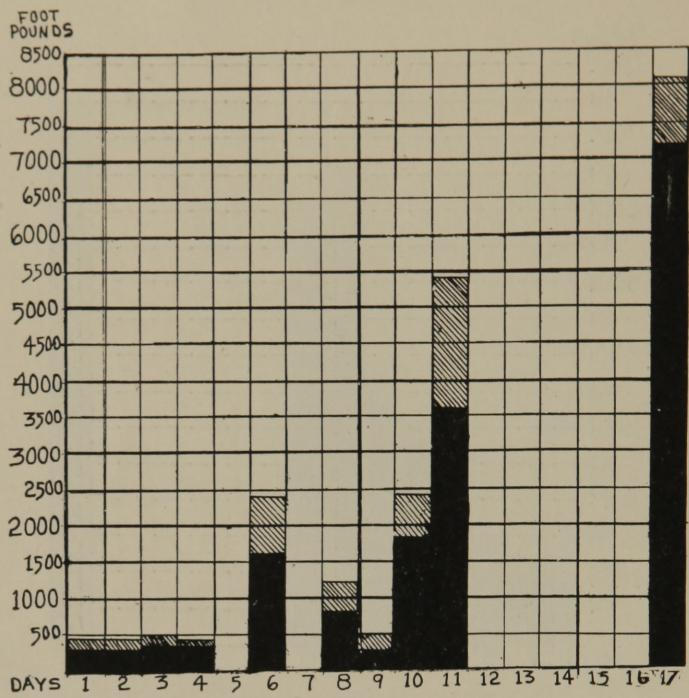

Chart 5

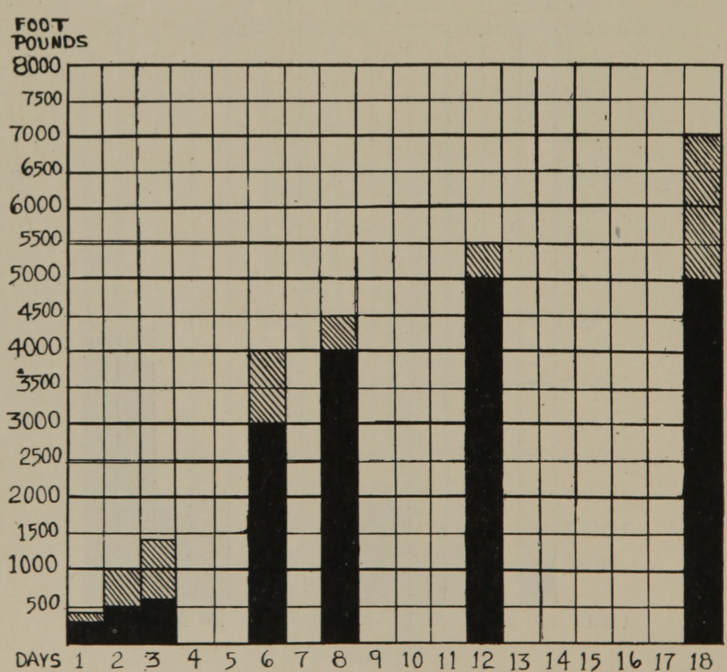

Chart 6

Charts 5 and 6.—These are like charts 3 and 4. They show the same progressive change in circulatory reactions. Chart 5 is from the patient R. F. in Table 1; Chart 6 is from the patient M. O. in Table 1.

improvement and increased activity. Patients R. F. and C. B., who show a late development of this phenomenon, were subjectively weak and improved very slowly before the time at which the objective improvement in the circulatory reactions began. Synchronously with the objective improvement there was marked subjective and clinical improvement.

In the cases I. M., C. B., R. F. and M. O., which were followed carefully with daily readings, it will be noted that this change in the circulatory reactions is most marked during a period of a very few days. In the case of I. M. the change in four days was from 1,500 to 6,500 foot-pounds. In the case of R. F., in two days the point at which the delayed summit appeared rose from 500 to 5,000 foot-pounds C. B. rose from 1,500 to about 5,000 foot-pounds in two days. M. C. changed from about 1,000 to above 3,000 in two days.

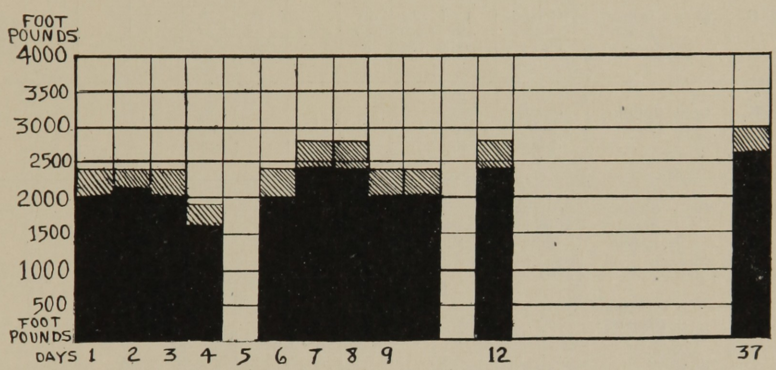

Chart 7.—This chart shows the circulatory reactions to exercise in a normal woman taken day after day. Note that the daily variation is comparatively slight. Compare with Charts 3, 4, 5 and 6.

That this change is not a mere result of the exercises to which the patient is subjected in the process of trying out his circulatory reactions is shown by the control Chart 7. The control was a normal woman not used to exercise. Observe that there is no marked change produced by the amount of exercise necessary to try out her circulatory reactions.

Table 1 summarizes our results in this series of patients.

When the method of frequent readings is used we obtain a result something like that shown in Chart 8, which is taken from the case R. F.

Both the slow readings and the rapid readings are given, and it will be observed that they both give exactly the same conclusions as regards the circulatory reactions. The readings taken at thirty, sixty and ninety seconds with the rapid method compare well with the same readings taken with the infrequent method. We have observed this

TABLE 1.—CHANGE IN REACTION OF THE SYSTOLIC PRESSURE TO EXERCISE DURING CONVALESCENCE *

Patient	Age	Disease	Recovery	Circulatory Reactions to Exercise Days									
I. M.	22	Lobar pneu-monia	Crisis —9 days	1 1,200 900	2 1.200 1,000	3 1,400 1,120	4 2,800 2,100	5 3,060 2,800	6 3,600 3,420	7 6,600 6,160	8 6,160 5,500		21 7,500 6,600
C. B.	40	Lobar pneu-monia	Crisis —6 days	1 750 500	3 1,000 750	4 750 400	5 1,600 1,200	6 1,600 1,200	10 1,400 1,000	11 1,400 1,200	12 3,800 3,300	13 5,400 3,600	
R. F.	41	Lobar pneu-monia	Lysis —6 to —3 days	1 450 300	2 450 300	3 500 460	4 450 360	6 2,400 1,600	8 1,200 800	9 500 300	10 2,400 1,800	11 5,400 3,600	17 8,100 7,200
M. O.	23	Lobar pneu-monia	Crisis —3 days	1 450 300	2 1,000 500	3 1,400 600	5 4,000 3,000	8 4,500 4,000	12 5,500 5,000				18 7,000 5,000
B. M.	44	Typhus	Crisis —9 days	1 1,300 1,100					6 2,500 2,100				
B. B.	27	Lobar pneu-monia	Crisis —12 days	1 2,300 1,800						7 3,500 3,000			
C. G.	22	Fibrinous pleurisy		1 200 0			4 2,200	5 3,500					
J. O.	21	Typhoid	Lysis —1 to +2 days	1 600	2 1,100 600			5 1,100				9 2,600 1,800	20 5,300
W. M.	..	Lobar pneu-monia	Crisis —3 days	1 400 200						7 1,400 800		9 1,600 1,200	
H. R.	21	Lobar pneu-monia	Crisis —15 days	1 1,900 1,500		3 4,000 3,200	4 5,000 4,000						

* The lower numeral of each pair gives the greatest amount of work, calculated in foot-pounds, which was not followed by a delayed summit. The upper numeral gives the smallest amount of work which was followed by a delayed summit. For example: Patient I. M. was tested for the first time nine days after his crisis and showed a delayed summit with 1,200 or more foot-pounds of work, while with 900 foot-pounds or less he showed no delayed summit. Twenty-one days later he showed a delayed summit with 7,500 foot-pounds of work or more and no delayed summit with 6,600 foot-pounds or less. Note: The patients, I. M., C. B., R. F., and M. O., have their reactions represented graphically in Charts 3, 4, 5 and 6, respectively.

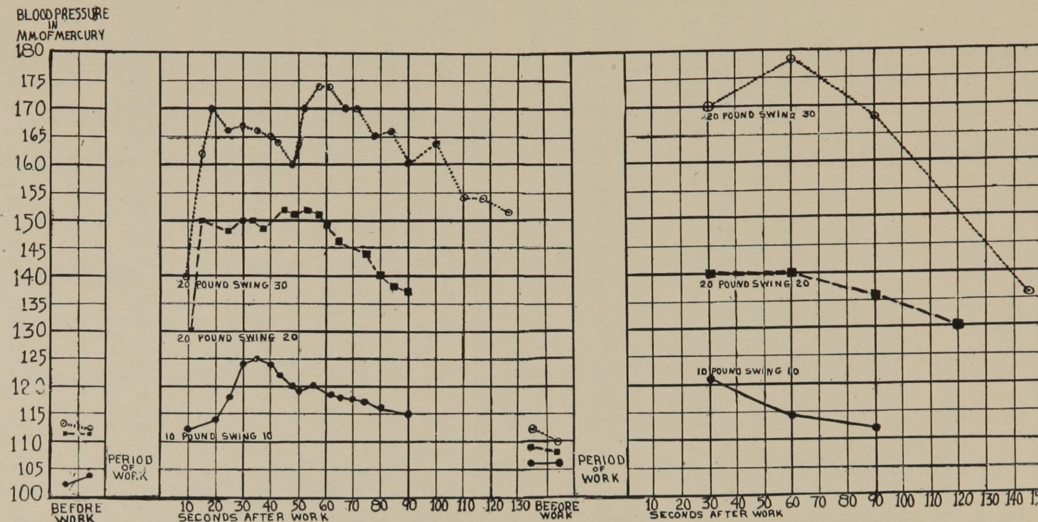

CHART VIII

Chart 8.—This is a comparison of the frequent and infrequent methods of taking the systolic pressure after exercise. Note that the readings taken at thirty, sixty and ninety seconds by both methods give curves which correspond very closely. The work was all done on the same day and the patient rested from five to ten minutes after each exercise.

same correspondence whenever we have compared the two methods. The infrequent or slow method, while it does not give us such detailed information about the exact shape of the curve, does give us the information which we have found to be of the most value; that is, whether or not there is a delayed summit. It is a method which is much easier to use, since it requires only one examiner, while, with the frequent reading method, two persons are required, one to read and one to record. For practical work the Barringer method has the advantage of simplicity combined with adequacy.

EFFECT OF EXERCISE ON THE PULSE RATE

Table 2 shows the pulse reactions to exercise of nine patients who were recovering from infectious diseases. The presence or absence of a delayed summit of systolic pressure after exercise is also recorded for purposes of comparison. It will be observed that the table shows thirty-two delayed summits, twelve of which show a delay in the return of the pulse to normal, while in the other twenty there is no such delay shown.

In general, the rate increases with increased amounts of exercise and takes an increasingly longer time to return to normal with increased amounts of work, but this general rule has many exceptions, especially in patients who show a marked slowing after exercise, probably due to nervous influence on the heart rate.

We have been able to make no deductions of value from the effects of work on the pulse rate or from the time required for the rate to return to normal after work in this small series of patients.

The agreement of our objective circulatory findings with subjective and clinical changes in the patients whom we have examined has been very striking. Our observations on different convalescent patients have shown a marked similarity and the results of these experiments afford evidence of considerable importance in support of the contention advanced by Barringer[1] that a delayed summit indicates an overtaxing of the cardiac reserve power.

Any method which will permit of fairly accurate objective measurement of the stage of convalescence has abundant possibilities of development and of use, both in the immediate present and in the future. It is most important at present that the convalescence of our soldiers be expedited as much as is consistent with good therapeutics. For the maximum of efficiency in this direction some standard objective method of testing the soldier's ability to resume active service is of great importance. Such a method these experiments seem to indicate.

So far the method of testing the circulatory reactions to exercise has been applied only to patients convalescing from acute infections. There is considerable probability of our getting useful information from the application of this method of study to patients who are recovering from the more chronic affections.

TABLE 2.—Effect of Work on the Pulse Rate of Patients During Convalescence *

Patient	Work	Pulse Rate		Return to Normal, Seconds	Delayed Summit	Delay, Seconds
		Before	Immediately After			
	Times					
M. O.	Sat up 5	68	86	180	No	
	Sat up 10	68	92	180	No	
	Sat up 15	80	88	120	No	
	7 lb. swing 5	96	108	120	No	
	7 lb. swing 10	88	108	120	No	
	10 lb. swing 10	90	114	120	Yes	58
	7 lb. swing 5	92	96	120	No	
	7 lb. swing 10	88	104	120	No	
	10 lb. swing 10	84	108	120	No	
	10 lb. swing 15	84	112	120	No	
	20 lb. swing 15	84	124	180	No	
	10 lb. swing 5	96	108	180	No	
	10 lb. swing 10	92	108	180	No	
	10 lb. swing 10	92	112	120	No	
	10 lb. swing 20	98	124	180	No	
	20 lb. swing 20	96	144	180	Yes	60
	20 lb. swing 10	104	128	120	No	
	20 lb. swing 15	104	140	180	No	
	20 lb. swing 25	104	158	180	Yes	60
	20 lb. swing 35	104	156	240	Yes	60
W. M.	Sat up 5	58	60	60	No	
	Sat up 10	60	72	120	Yes	60
	10 lb. swing 25	80	116	90	No	
	20 lb. swing 20	84	132	120	Yes	60
	20 lb. swing 15	90	112	118	No	
	20 lb. swing 20	96	124	120	Yes	60
	20 lb. swing 25	96	128	120	Yes	60
C. B.	20 lb. flex 10	68	84	120	Yes	60
	20 lb. flex 20	68	88	120	Yes	60
	10 lb. flex 15	68	84	60	No	
	10 lb. flex 20	72	80	120	No	
	10 lb. flex 30	74	92	120	No	
	10 lb. swing 10	72	100	120	No	
	10 lb. swing 20	84	108	120	No	
	20 lb. swing 20	72	132	240	No	
	20 lb. swing 30	76	144	150	Yes	60
	20 lb. flex 15	50	76	120	No	
	20 lb. flex 20	54	72	90	Yes	60
	20 lb. flex 30	54	76	120	Yes	60
R. F.	Sat up 10	76	82	120	No	
	Sat up 12	72	88	120	No	
	Sat up 15	72	88	120	Yes	61
	10 lb. swing 10	64	88	120	No	
	20 lb. swing 20	68	112	120	No	
	20 lb. swing 30	68	128	240	Yes	55
	20 lb. swing 30	88	120	150	No	
	20 lb. swing 35	84	136	240	No	
	20 lb. swing 40	84	140	300	No	
	20 lb. swing 45	84	148	360	Yes	60

* The exercises in each group were given on the same day and five to ten minutes intervened between individual exercises. The figure 120 in the column headed "Return to Normal" means that the rate became normal in two minutes or less.

TABLE 2.—Effect of Work on the Pulse Rate of Patients During Convalescence *—(*Continued*)

Patient	Work	Pulse Rate		Return to Normal, Seconds	Delayed Summit	Delay, Seconds
		Before	Immediately After			
	Times					
E. W.	Sat up 10	52	72	180	Yes	90
	Sat up 15	52	72	180	Yes	90
	Sat up 20	48	72	120	Yes	150
	Sat up 10	40	48	120	Yes	90
	Sat up 15	40	52	120	Yes	90
J. O	7 lb. flex 21	112	128	120	Yes	90
	7 lb. flex 30	112	136	250	Yes	210
	7 lb. swing 5	96	112	120	Yes	60
	7 lb. swing 10	104	124	120	Yes	120
	10 lb. swing 5	108	120	180	No	
	10 lb. swing 5	96	112	120	No	
	10 lb. swing 10	92	108	180	No	
	10 lb. swing 15	100	120	120	No	
	10 lb. swing 20	96	92	180	Yes	58
	10 lb. swing 10	112	120	120	No	
	10 lb. swing 15	112	124	120	No	
	10 lb. swing 20	108	136	180	No	
	20 lb. swing 20	112	156	300	No	
	20 lb. swing 25	120	160	180	No	
	30 lb. swing 20	116	168	300	No	
I. F.	10 lb. swing 5	72	88	120	No	
	10 lb. swing 10	72	104	180	No	
	10 lb. swing 15	76	104	180	No	
	10 lb. swing 20	88	88	300	Yes	120
J. E.	10 lb. swing 10	76	88	120	No	
	20 lb. swing 10	72	92	180	No	
	20 lb. swing 15	80	108	120	Yes	60
	20 lb. swing 15	72	92	120	No	
	20 lb. swing 20	76	100	120	Yes	60
C. G.	10 lb. flex 10	112	116	120	Yes	60
	10 lb. flex 15	108	112	180	Yes	61
	10 lb. flex 10	96	130	180	No	
	10 lb. flex 15	104	104	180	No	
	10 lb. flex 20	100	108	120	No	
	10 lb. flex 25	104	104	180	No	
	15 lb. flex 20	100	136	180	No	
	10 lb. swing 10	112	116	120	No	
	10 lb. swing 15	112	120	120	No	
	10 lb. swing 10	104	116	120	No	
	10 lb. swing 20	104	116	120	Yes	60

SUMMARY

1. The circulatory reactions of ten patients convalescing from acute infectious disease have been studied objectively.

2. The pulse reactions have not given us any information of value.

3. The blood pressure reactions have shown a progressive increase in the amount of work necessary to produce a "delayed summit." This increase has been shown in all cases, has been especially marked in a short period of a very few days, and has been synchronous with clinical and subjective improvement.

CONCLUSION

The reaction of the systolic blood pressure to exercise in a convalescent patient affords valuable objective evidence of the stage of the patient's convalescence.

I wish to express my indebtedness to Dr. Alfred Meyer, Dr. Emanuel Libman, and Dr. Morris Manges for permission to follow the convalescence of patients on their wards.